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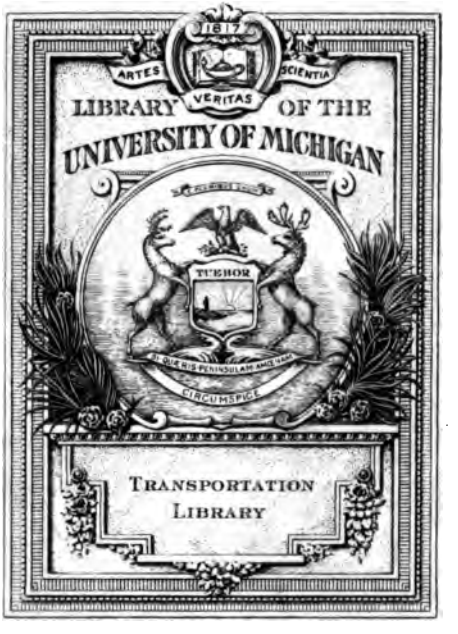
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W. Bridges Adams

THE VARIETIES

OF

PERMANENT WAY,

PRACTICALLY USED, OR TRIED, ON RAILWAYS
UP TO THE PRESENT PERIOD.

By WILLIAM BRIDGES ADAMS.

(To which a Telford Medal was awarded, Session 1856-57.)

AND

ON SOME RECENT IMPROVEMENTS

IN THE

PERMANENT WAY OF RAILWAYS.

By P. M. PARSONS, Assoc. Inst. C. E.

WITH AN ABSTRACT OF THE DISCUSSION UPON BOTH PAPERS.

EDITED BY

CHARLES MANBY, F.R.S., M. Inst. C.E.,
SECRETARY.

BY PERMISSION OF THE COUNCIL.

EXCERPT MINUTES OF PROCEEDINGS
OF THE
INSTITUTION OF CIVIL ENGINEERS,
Vol. XVI.
SESSION 1856-57.

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1857.

INSTITUTION

OF

CIVIL ENGINEERS.

February 3, 1857.

G. P. BIDDER, Vice-President,
in the Chair.

No. 947.—"The Varieties of Permanent Way, practically used, or tried, on Railways, up to the present Period."[1] By WILLIAM BRIDGES ADAMS.

IN the session of 1851-52, the Author presented to the Institution, a Paper "On the construction and duration of the Permanent Way of Railways in Europe."[2] Several of his views were then strongly contested, but as some time has elapsed since that discussion took place, he is now induced to return to the subject, with an increase of practical experience.

If, as is generally acknowledged, the "Permanent Way" of railways is, for the most part, anything but permanent, it must not be forgotten, that it has ceased to be sufficiently permanent, chiefly because the locomotive engines, now used, are double the weight of those for which the original lines were designed. The calculations of Engineers have been baffled by the increase of traffic, and the proportion of the strength of the road to the weight of the engines has to be settled anew.

It is advisable then, in the first place, to determine what are the mechanical principles essential to the efficient construction of Permanent Way. The first principle to be attained is non-deflection,

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[1] The discussion upon this, and the subsequent Paper extended over portions of four evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xi., pp. 244 to 273.

7-31-57

either vertically, or laterally,—not absolute non-deflection, but so much stiffness in the rail itself, as will distribute the pressure equally over a considerable space, so as not to crush, or disturb the ballast, or bearing surface, with a constant short wave of rail rising in front of the engine-wheels, by the yielding of the ballast beneath the weight. In proportion as the rail is strengthened, or the engine is lightened, so will be the perfection of the road, and the greater will be the proportion of duty obtained from the locomotive.

The second principle must be, such an arrangement of the joints of the rails, as, while permitting expansion and contraction in each length of rail, will preserve, as nearly as possible, equal strength of resistance over the whole surface. For though the theory of a continuous bar without joints, may be practically borne out, in peculiar portions of a line, still, rails, for various practical reasons of manipulation, must continue to be in lengths, with joints between the lengths. If the joints be weaker than the intermediate portions, the diminishing resistance will approximate to the condition of a blow, and *vice versâ*, if they be stronger. It would be better to have a rail of too much deflection, provided it was of equal strength throughout, than to have a non-deflecting rail, with weak joints.

The third principle is to have the surface of the rails so constructed, as to prevent any mechanical change, such as laminating, or crushing, from rapidly taking place by the action of the wheels rolling over them. This may be accomplished in two ways, either by condensing, or hardening the surface, or by widening the rails and increasing the amount of bearing; in both cases the surface must be equally hard, or equally wide throughout. A soft interval in a hard surface, will be equivalent to blows destroying the rail; and such would be the case, also, if the irregular tilting of the rails laterally, were to cause a variation in the tread of the wheels.

The fourth principle is, that the rails must have such an amount of bearing surface below them, either by their own structure, or by the intervention of sleepers of sufficient area, as to prevent their crushing into the ballast, or ground on which they may be laid. At the same time, it must be borne in mind, that the surface of the rail itself must be sufficient, either by its own width, or by some artificial extension of its width, such, for example, as chairs supply, to prevent it from crushing the sleepers. The attachment to the chair and sleeper should be of such a kind, as to permit of no loose movement, which might induce hammering and destruction.

The fifth principle is, as far as possible, to use only such materials in the construction of the way, as, while mechanically strong enough, or rather with some surplus amount of mechanical

strength, will also be effectively durable. The perception of this, no doubt, led the late Mr. George Stephenson to use stone blocks for sleepers, and the principle was sound, and had not the hurry of making Railways prevented the thorough working out of the details, they might probably have been continued in use.

The sixth and last principle is, the medium on which the way is to be laid. On solid ground, porous ballast is preferred,—in order to drain away moisture. In boggy ground, a floating medium is required, and the tanning property of bog-water renders wood of any kind a very durable material, as it prevents its chemical destruction.

Many varieties of Permanent Way may be made to comply with these principles, and in choosing between them, the consideration should be, which of them can, with equal efficiency and durability, be made to combine the greatest simplicity with the smallest cost, both in outlay and in maintenance.

Reasoning on the foregoing principles, it is obvious, that the deeper the rail can be made, the greater will be its vertical strength to resist deflection. But the mode of its application may involve much difference in cost. If the rail be insistent, or supported on its base, the vertical web must be sufficiently stiff, to prevent it from buckling under the downward pressure; and the breadth of the lower web, or foot, or of the chair, must be increased in proportion to the height. An ordinary bridge rail is 6 inches in width and 3½ inches in height; the horizontal base being as twelve to seven of vertical elevation. It is obvious, that the closer the tread surface of the rail is to the bearing surface on the ballast, the less will be the tendency to rocking, or oscillation; and how this arrangement may best be reconciled, with such a depth of rail as will prevent deflection, is a problem which it is desirable to solve.

Beginning chronologically, it will be remembered, that the earliest rails were merely wooden planks, laid on the "way leaves" in the North of England. As these planks wore away, they were replaced with iron bars. Cast-iron tramways succeeded, and they were, in time, replaced by wrought-iron tramways. The great revolution was, removing the guiding flange from the rail and placing it on the wheel, and using what was early called the "edge-rail." By this plan, dirt, or obstructions, are not liable to collect in the path of the wheels, the tread of the wheels being elevated above the bearing surface.

The rail assumed, at once, the most obvious form, that of a T bar, with the vertical portion deep enough to bear the insistent load, and the horizontal portion an inch and three-quarters in width, which was considered sufficient to serve for lateral stiffness, and for the tread of the wheels. This form of rail neces-

sitated the use of chairs to support it, and these were made of cast iron.

Two other classes of rails were subsequently adopted, apparently with a view to get rid of chairs; the foot, or contractor's rail, and the bridge rail. The first is, owing to the difficulty of rolling, only made about 4 inches wide at the base, and this could not be increased without very wastefully thickening the iron at the foot. The height was usually about 3 inches, but latterly it has been increased to 4 inches, and upwards.[1] Thus the height is, in many cases, greater than the base, and it should, therefore, be used with appliances to widen the base. Used as it is in America, by merely spiking down with dogs on the edges upon fir sleepers, it can only be a source of constant repairs. The bridge rail, in the process of manufacture, offers facilities for widening the base to any desired extent, and also for giving any height required. But, as it is composed of two vertical webs, the weight is very materially increased, as compared with other rails. A bridge rail 5 inches in height, with a base of 8 inches, would weigh about 100 lbs. per yard.

The next in order is the double I rail, which, from the period of its first introduction by Mr. Locke, V.P., has been more largely used than any other. One advantage it possesses, is its facility of being reversed. In ordinary practice, the process of reversing is commonly adopted for crushed, or flawed rather than worn rails, as the latter will not fit in the chair when reversed. It is advisable to point out how this occurs, for the popularity of this rail has led to numerous attempts to improve the mode of fastening. The sectional form of the rail imperatively demands an artificial base. The ordinary chair supplies this. The apparent reason for the peculiar form of the chair, is the facility of removing and replacing the rails, by driving out the keys, without disturbing either the chair or the sleeper, of which the chair is supposed to become a part. The 'tables' of the rail form a double parabola, and generally not more than two inches, and sometimes less, of the bottom table bears upon the chair, and then it rests on a slope, to which it is confined by the wood key, or, as a variation, by iron keys. The lateral blows of the wheels continually compress the keys, the rail becomes unsteady, springing up and down, and laterally, as may be detected by the noise, and as is proved by the channels cut across the rails and across the chair seats. This effect is more conspicuous since the increase in the weight of the engines; but the process was always in operation. Wherever a blow exists, it indicates a deficiency of adjustment, and moisture causes rust, which is rubbed off and renewed, till, partly mechanically and partly chemically,

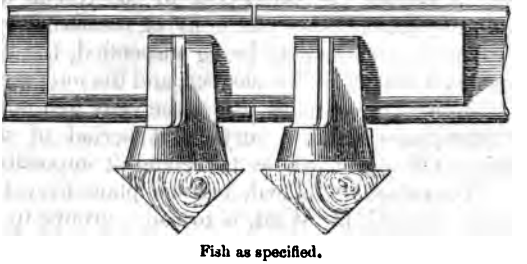
[1] Since this was written, this class of rail has been manufactured with a considerably extended height and base.—W. B. A.

the rail becomes useless. There is another disadvantage in the use of the chair. The seat, or bottom, cannot, with certainty, be less than 2 inches in thickness,—and as the depth of the rail is 5 inches, this makes a total of 7 inches, or adding the thickness of the sleeper, a total elevation of about 12 inches above the bearing on the ballast. A chair of 10½ inches to 11 inches in length is necessary to hold firmly to the sleeper. The raising of the rail so high, gives a mischievous leverage to the lateral blows of the wheels, and tends to spring the sleepers, and disturb them in the ballast. Of course, so long as the rail and chair are firmly fixed together by these fastenings no blows take place.[1]

Up to the year 1847, but few attempts had been made to improve the joints of the rails. On the Blackwall Railway, a vertical scarf joint had been effectively used to obtain a continuous surface, before locomotives were employed on it; and Professor L. D. B. Gordon subsequently tried a horizontal lap on the Eastern Counties Railway. But, in both cases, entire dependence was placed on the chairs and sleepers, to keep the rails in position; as the rails were not formed into continuous bars, independently of the sleepers.

In that year, the double I rails in use on the Eastern Counties Railway were found to be so frequently damaged at the ends, by the rolling of the wheels above, and the hammering in the chairs below, that it was impracticable, any longer, to keep them firm. To remedy this evil, the Author specified the plan of removing the joint chair and sleeper three inches back from the joint, and applying another chair and sleeper three inches on the other side of the joint. An iron 'fish,' resting in, and supported by the two chairs, was then placed in each rail channel, so that the joint became, as it were, suspended (Fig. 1). This had

Fig. 1.

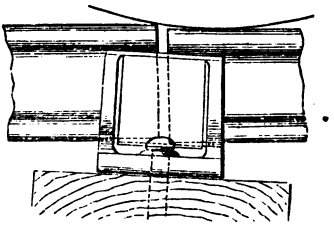


Fish as specified.

[1] In the United States, the battering of the ends of the rails in the chairs is so excessive, that an india-rubber bearing is said to have been adopted with great advantage. A continuous bearing of cork has also been laid experimentally, for upwards of two years, under bridge rails, on one of the metropolitan lines, to prevent vibration on girder bridges.—W. B. A.

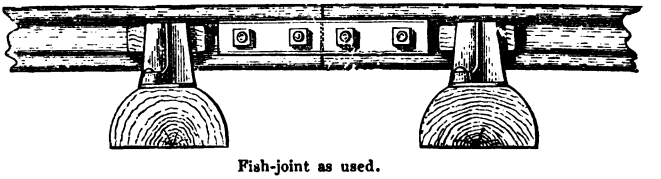
the effect of converting each rail into "a beam fixed at the two ends," which was not the case with an ordinary joint chair, in which the wear of the wood key leaves the rails loose, so that the end of each rail springs up before the wheel arrives, and is beaten down when the wheel passes over the joint (Fig. 2). The desire to avoid casting fresh chairs, for the additional number required by the 'fishing' process, led to removing the chairs to 20, or more, inches apart, and to bolting the fishes to and through the rails, by four bolts (Fig. 3). In some cases the fishes were applied, by simply removing the joint sleeper, leaving a distance

Fig. 2.



Sunk Sleeper.

Fig. 3.



Fish-joint as used.

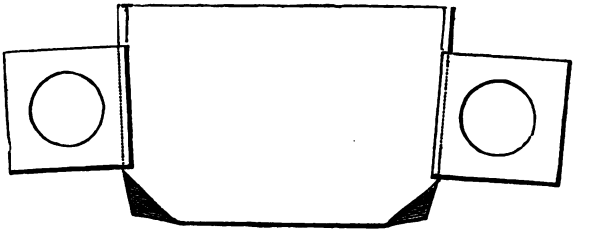
of from 3 feet to 4 feet, between the other sleepers, unsupported, the result of which was the breakage of the bolts. The chief defect of the double I rails under the modern heavy engine,—want of lateral stiffness,—is aggravated by this arrangement.

There is no doubt, that a good firm joint can be made, with the chairs 20 inches apart, by bolting the fishes to the rails, so long as the fishes fit, and the bolts are kept tight. But it is obvious, the form of the rail channels is not that best adapted to keep the fishes firm. The inside angle of the tables of the rail is about 45°; and, consequently, the fishes can only be retained by the end tension of the bolts. The joint being suspended, the vibration of the trains is not absorbed by the sleeper, and the nuts are gradually jarred loose. When this takes place, the rails wedge themselves in between the fishes, and a very short period of neglect, so damages both rails and fishes, as to render it impossible to keep them tight. To remedy this evil, various plans have been tried. One, by the late Mr. C. H. Wild, is to roll a groove in the fish, to prevent the bolt-head from turning. A second, by Mr. W. Pole, (M. Inst. C. E.,) is to tap the screws of the bolts into one of the fishes. Another plan is to use double nuts. There is no doubt, that the fish joints wear out, and are not absolutely permanent. This is due to the section not being deep enough vertically, so that the

fishes are apt to bend and set, and to their not fitting closely in square-cornered channels of the rails. But, with rails used in the ordinary mode, this would not be practicable, for unless the corner be well rounded, the table would break off. This difficulty has been experienced in other countries as well as in England. Mr. Bullard, an engineer of railways, Boston, U. S., writes to the Author: "Our roads have experimented with the common rolled plates for some years, but they do not prove of utility, and in many instances have been abandoned."[1]

The difficulty of keeping the bolts of ordinary fishes tight has been found to be so serious an evil, that the Author was led to devise a simple plan of keying them (Fig. 4). The bolt-heads and

Fig. 4.



Lock-bolts for Fishes, or Brackets, or other Rail Fastenings.

nuts have edges bevelled to an angle of 45°, where they press against the fish plates, so that they form a kind of groove, when the bolts are screwed tight. A thin wedge plate, with a bevelled edge, is driven into the grooves, between each pair of nuts, and if the nut is not screwed quite tight, the wedging action will tighten it. The lower corners of the wedge being bent upwards, it is fast, and the bolts cannot get loose, unless by becoming lengthened, by the rails opening the wedge angle of the fishes.

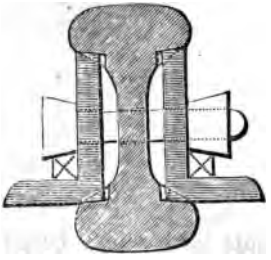
The want of fit between the fishes and the rails, led the Author to suggest that the channels of the rails, wherein the fishes abut, should be made of a square form, by pressing them between dies whilst hot. Two, or any other number of punches may be inserted

[1] Since this was written, the Author has examined many fishes which were purposely taken up by the engineer on one of the metropolitan lines. They presented the appearance of a bar bent downwards in the centre, and were, practically, bent bars, though the bending was produced by attrition. On the upper and lower edges, a projecting cross-rib was left between the ends of the rails, indicating the original level of the metal, and an indentation was made in the rails, on the lower side, at the ends of the fishes. This result was produced by the injudicious practice of suspending the rail joints between distant supports. The object of the Author, in originally suspending the joint between the chairs, was to obtain a firm bearing,—not to be obtained in the battered rail ends of existing lines,—the distance being then only six inches between the chairs.—W. B. A.

in the upper die, so that when, by pressure, or by blows, the dies are forced together, the side channels will be squared for the length of the fish, and the bolt-holes be punched at the same time. The squeezing of the metal from the inner sides of the tables of the rails, will condense the material of the ends advantageously, as well as make an accurate joint for the fishes. When the rail leaves the rolls, one end may be at once cut off and pressed; the rail may then be allowed to cool, and afterwards the other end may be heated and pressed, by this means the lengths of the rails will be more accurate; or, the rails may be cut as usual, and the ends be stamped and punched, one after the other.

The improved fishes to be used with the rails thus prepared, are rolled with a projecting rib at the bottom edge, and are made to fit the rail, with a very slight wedging action (Fig. 5). The bolt-heads and nuts are slightly pyramidal, and of such a size, that they can just turn round clear of the rib. Keys are driven in between the bolt-heads and the nuts and the rib, so that the bolts cannot work loose. Moreover, on account of the squared channels, there will not be any wedging strains on the bolts, and the additional breadth, due to the ribs, will afford increased lateral strength, as compared with the ordinary fish. An improvement on this plan, is to use a rail prepared in the same manner, with wrought-iron brackets, and bevilled bolts and nuts, keyed below, dispensing with the two joint chairs and fastenings, required when fishes are used.

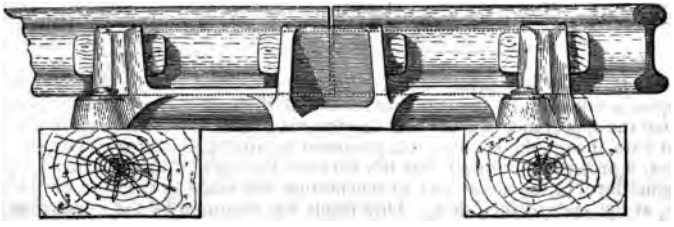
Fig. 5.



Recessed Fish and Bracket Joints.

The next class of joint practically used, is that introduced by Mr. John Fowler, (M. Inst. C. E.,) on the Manchester, Sheffield, and Lincolnshire Railway, in 1849 (Fig. 6). This was a large

Fig. 6.



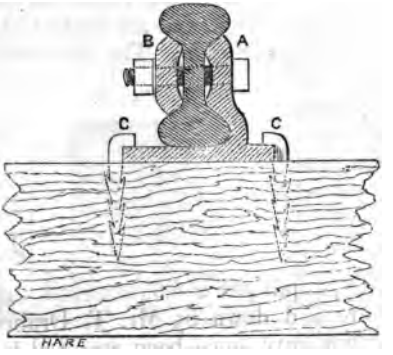
Fowler's Joint Chair.

casting, 2 feet 6 inches in length, being practically three chairs cast

together, and resting on two sleepers, the rails being confined by three ordinary wooden keys. The great length of bearing was no doubt advantageous, in saving the lower table of the rail from damage; but if the timber is not sufficiently firm to prevent the rails from springing, the rails cannot come under the category of "beams fixed at the ends."

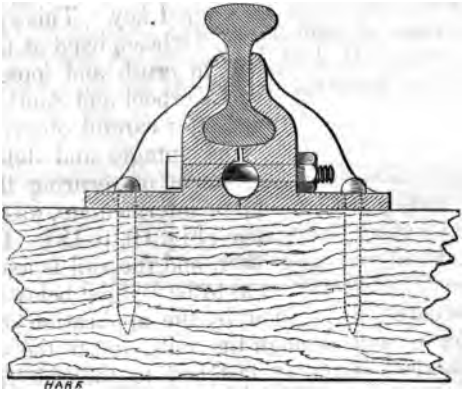
In the year 1850, Mr. James Samuel, (M. Inst. C. E.,) produced his fish chair, which is a combination of a chair, with one jaw elongated, and of a fish of wrought iron, bolted together, to and through the rails (Fig. 7). The object of this fish chair was to save the expense of laying down another sleeper with its chairs. This plan involves a mechanical difficulty. To make castings to fit the surfaces of the channels of the rails, against the top and bottom web, and below the bottom web, is scarcely practicable; the more especially, when it is recollected that rails constantly vary in their section, by the wear of the rolls.

Fig. 7.



About the same period, June 1849, Mr. Peter W. Barlow, (M. Inst. C. E.,) produced a chair in two halves, bolted beneath the rails (Fig. 8). This was not subject to the defect of

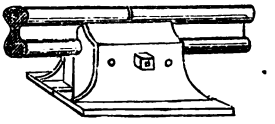
Fig. 8.



Mr. Samuel's one-jawed chair, inasmuch as it took no bearing on

the upper portion of the rail, but merely clipped the lower table. The great height of this rail above the sleeper, and the leverage of the rail on the two half chairs, have a tendency to loosen them; and for this reason, it would appear, that their use has been rather experimental than practical, the fish joint being used in preference on the Midland Railway. In this arrangement, Mr. Barlow had been anticipated by a Mr. John Day, as early as January 1835. Fig. 9 is taken from a lithograph entitled "John Day's Patent Cast-Iron Base Plates for Railways." These base plates were proposed to be used as chairs, in two parts, and to be bolted down on wooden sleepers; the bolts passing through the two half chairs below the rails, as in Mr. Barlow's plan.

Fig. 9.



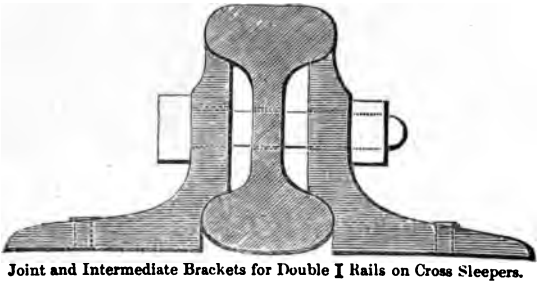
Day's Cast-Iron Base Plates.

In 1852, Mr. Mansel produced, on the South Eastern Railway, a peculiar kind of joint, of combined wood and iron. Short pieces of half balks of timber were grooved along their upper edges, the grain being vertical, and the grooves were brought together so as to form one groove. Two fishes were laid in the channels of the rails, and, when so prepared, the rails and the fishes were laid in the grooves. The timber was then clipped to and through the rails, by bars and cross bars with keys, and all was packed in the ballast together, forming practically, a split pile a foot in depth. A considerable number of these were laid down by Mr. T. Drane, (M. Inst. C. E.); but it is said, they have since been removed by a succeeding Engineer, and have been replaced by fish joints of the ordinary kind. This joint is shown in Plate 2, Figs. 2 and 11.

In the same year, Mr. McConnochie produced a new kind of chair, cast in two parts; one part being a cast wedge, sliding in with the rail, so that downward pressure kept it tight, while the upward rising was prevented by a wood key. This system, therefore, did not fulfil the condition of "a beam fixed at the ends," as the springing of the rail tended to crush and loosen the keys. These chairs were applied on the Liverpool and Southport Line.

In February 1853, the Author, after careful observation of the whole system of joints, and their advantages and defects, arrived at the conclusion, that the best mode of securing the double I rails to the sleepers, whether joint, or intermediate, was on the principle of the bracket, or ship's knee (Fig. 10, p. 12). The fish and the chair are abandoned altogether, and the rail is fixed on, or in, or slightly above, the sleeper, so as to be wedged below if preferred. The rail is secured in position by the application of knees, or brackets, bolted to and through the rails, and to the sleeper also, precisely as a deck beam is fastened to the side framing of a ship. That this was thought a good system may be assumed from

Fig. 10.

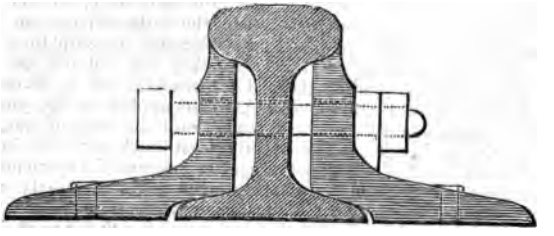


Joint and Intermediate Brackets for Double I Rails on Cross Sleepers.

the fact that Mr. C. H. Wild specified it one month after the Author, and Mr. Liddell twelve months later. It is now in use on the Great Northern, the South Western, the Western of France, and other lines, and is preferred to the fish joint, as it appears to be more durable, the bolts are less likely to be loosened, and the saving of outlay in repairing an old line amounts to about £150 per mile. This arrangement fulfils the conditions, of keeping the rail as low as possible on the sleeper,—2 inches lower than the chair system,—and of saving the lower table from damage by blows, while the worn top does not interfere with its being firmly fixed when reversed, so that it is really a reversible rail. There are no keys to get loose, and the bolts are saved from much vibration, by the structure being bedded on the timber. The joint brackets are 1 foot 6 inches in length, with four bolts, and weigh from 42 lbs. to 45 lbs. per pair. The intermediate brackets are 4 inches long, with one bolt, and weigh 11 lbs. per pair. The rails thus become "beams fixed at the ends." None of these brackets have broken on the Great Northern Railway, where tre-nails are used. Five have broken on the South Western Line, all exactly through the strongest part, in a line with the spike hole, evidently from too tight a fit of the spikes, which burst them just as a stone is broken by wedges.

These brackets can also be applied to the foot rail (Fig. 11),

Fig. 11.

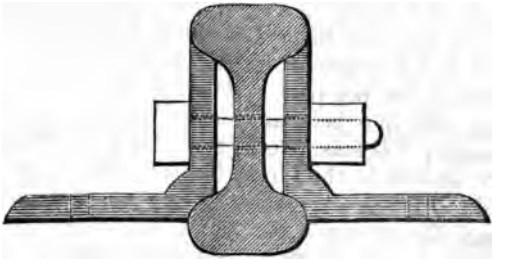


Joint and Intermediate Brackets for Foot Rails.

and when so used, form an extended base to the rails, preventing any rocking movement, by the side lurches of the wheels. With a single pair of intermediates in the centre of each rail, in addition to the joints, the whole will be kept very firm. They involve less cost than any other efficient method. Some of these brackets, both joints and intermediates, were laid down on the South Western Railway, near Kingston, in June 1855, and at Putney in September of the same year. They have given such entire satisfaction, that a further quantity is being laid down on the metropolitan extension of that line. Some have been made with the bearing surface extended in a thin web below the rails without touching them; but this method has the disadvantage of increasing the elevation of the rail, exposing it to leverage, and also increasing the quantity of the metal; though it tends to prevent the brackets from tilting inwards, if the bolts get loose. Should, however, the bolts get loose, the rails may drop down, and break away the central portion.[1]

In some cases the lower table of the rail has been grooved into the sleeper, by which the gauge and pitch of the rail is accurately secured, and all strain by the lateral blows of the wheel is removed from the holding-down spikes (Fig. 12).

Fig. 12.

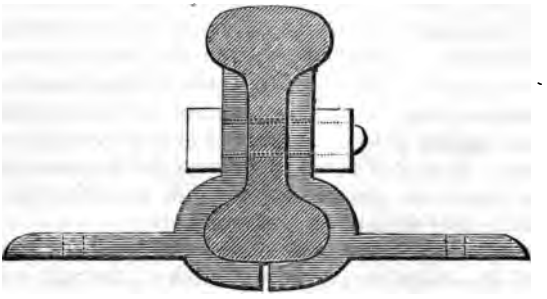


Joint and Intermediate Brackets for Double I Rails.

[1] A considerable number of these brackets, rolled in wrought iron, with an under lip below the rail, have been applied on the South Western Line, and with good effect. They are 15 inches in length, have four bolts, and weigh 42 lbs. per pair. They are made to fit the side channels of the rails accurately, between the upper and lower tables, and if any wear takes place, the rails will rest on the under lips. But in reversing the rails, it will be necessary to chip their edges, if they happen to be spread out in wear, and then they will not rest on the under lips, on account of the reduced surface. Cast brackets are to be used on the Direct Central Railway, and wrought-iron brackets applied to the joints of foot rails have been recommended for the Grand Trunk Railway of Canada. The Engineer of the North London is also adopting cast brackets for the joints of the Double I rails, and on the Great Northern, after two years' experience of thirty miles as laid, an additional length of sixty-seven miles is shortly to be laid. In examining cast-iron brackets which had been some time in use, loose bolts were found; but the rail joints were well preserved, by the inward pressure of the upper lips of the brackets beneath the rail table owing to their leverage on the sleeper. Key bolts, instead of screw bolts, may be used with the brackets if preferred.—W. B. A.

In other instances, a bracket chair, of wrought iron, in two parts bolted through the rail, to which it is closely fitted, and supporting the upper table, with the lower part recessed into the sleeper, has been used. These bracket chairs may be made of cast iron, but it is difficult to obtain an accurate fit of all the parts (Fig. 13).

Fig. 13.



Bracket Chair of Wrought Iron in Two Parts.

In February 1854, Mr. W. H. Barlow (M. Inst. C.E.) produced a new variety of joint chair, specified as a double wedge. It was a long chair, and instead of the ordinary wood key, two cast keys were drawn in close to the rail, along an inclined plane of the chair jaw, by a long bolt passing through the centres of the two wedges. The power of this bolt on the acute wedges is very great, and the result, when tried on the Great Northern Line, was the occasional longitudinal splitting of the chairs along the bottom. To remedy this, slips of wood were applied between the faces of the chair, and the wedges. The result on the Great Northern Line was unsatisfactory, as the wedges worked loose. The weight of this joint is very considerable; but, notwithstanding, it still requires much more iron to make it strong enough to resist the powerful action of the wedges. As it is, the slip of wood is crushed, and the wedge is pushed upwards. It is difficult to fit such a chair to the rail, and its use does not appear to extend, for it does not produce with the rail "a beam fixed at the ends."

In March 1854, Mr. P. M. Parsons (Assoc. Inst. C.E.) produced a joint chair of considerable size and weight, and of length sufficient to overhang the sleeper on each side. A powerful cast, or wrought iron wedge, of great weight, and about 18 inches in length, is driven between the rail ends and the chair, which, on this side, is lined with a piece of end-grained wood, as a kind of packing, inserted in a rebate, the opposite side of the chair fitting the rail channel. The action of the wedge upon the chair is very great, but Mr. Parsons has provided for this, by introducing strong

circular flanges, dipping below the sleeper, at each end. While the wedge remains tight, the rails are effectively fixed by the ends. This chair has been applied on the Great Northern Line.[1]

In July 1854, Mr. Wright produced what he denominates his vice jaw chair. This chair has one fixed and one loose jaw. The loose jaw is pressed against the rail by a hook head-bolt, passing below the rail, with the nut screwing up against the solid jaw.

A joint, by Mr. Barningham, of Manchester, has been tried on a line in Lancashire. It ought to be effective if made to fit. There are two castings, 2 feet 8 inches in length, filling the side channels of the rails: to and through which they are bolted with six bolts. They are spiked down upon two sleepers, with eight spikes to each joint. This will effectually hold the rails by the ends, but the cost will be very considerable. The section is similar to that of the Author's chair-brackets, with the lips turned under the rail (Plate 2, Fig. 10).

Whether owing to the price of iron, or from a desire to lower the rail on the sleeper, or to get rid of the hard seat on the chair, or all these combined, an experiment was made, on the Rouen line, in December, 1853, of using wood brackets, or knees, to secure the rails to the sleepers. The rail was bedded in a shallow groove across the sleeper, and two pieces of oak timber notched into the sleeper on each side of the rail at an angle pressed end-grain against the side channels, being secured by screw bolts into the sleeper. This was so far approved, that by the end of 1855 there were laid down on various lines,—

	Kilometres.
From Mantes to Caen	30
Fecamp	20
Du Nord	6
D'Orleans, Station of Etampes	5
Poitiers à Niort	6
Strasbourg, Parisian Terminus	8
L'Enett, Alençon	10
Lyons, Dole à Salins	10
Grand Central	50
Total	145

This is analogous to the wood brackets, described and illustrated by the Author in his former Paper[2] (Fig. 14.)

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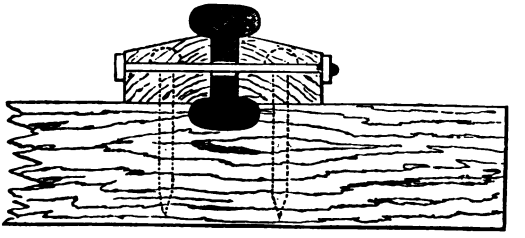
[1] Mr. Parsons' improvements in Permanent Way are explained at greater length, in a Paper by that gentleman, *vide* p. 35.—Ed.

[2] *Vide* Minutes of Proceedings, Inst. C.E., vol. xi. p. 249.

Fig. 14.

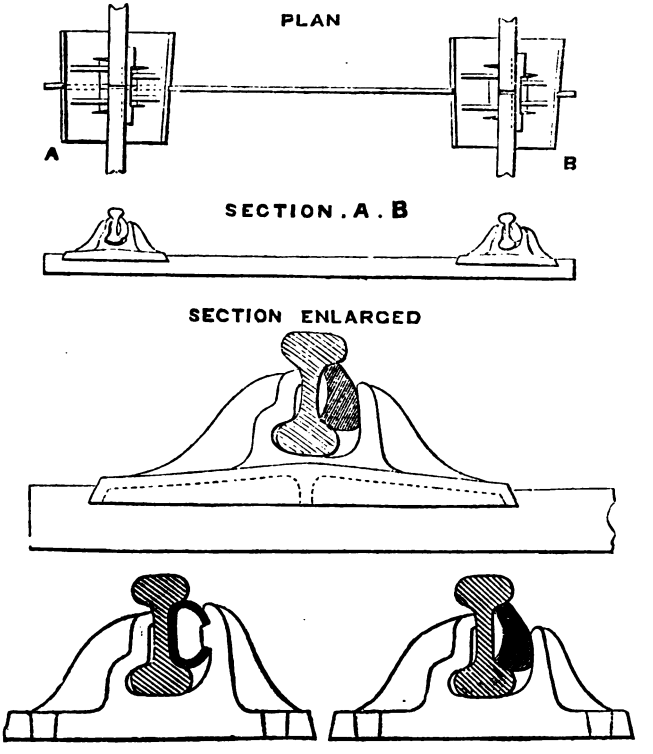


Rail without Chairs.

It is stated, that the saving by substituting wood for cast-iron chairs in France, amounts to about three francs per running metre.

The last joint that the Author is aware of, is by Mr. B. Burleigh (Assoc. Inst. C.E.) (Fig. 15.) It is in use on the Great Northern

Fig. 15.



Burleigh's Cast-Iron Chair, and Key.

Railway, and is said to stand well.[1] It is simply a long and heavy chair, with a long and heavy cast-iron key, or an elastic wrought key, judiciously fitted on one side in the channel of the rails, and on the other side bearing against the jaw of the chair low down, so as to put very little breaking strain on it. The angle is very acute, and the keys are placed in the chairs, in such a direction that the action of the trains tends to tighten them.

Mr. H. Greaves has recently introduced some improvements in joints and fastenings. In one case he places one fish in the rail channel in the ordinary joint chair, and secures it by a wood key, and also by bolting it externally to the rail (Fig. 16).

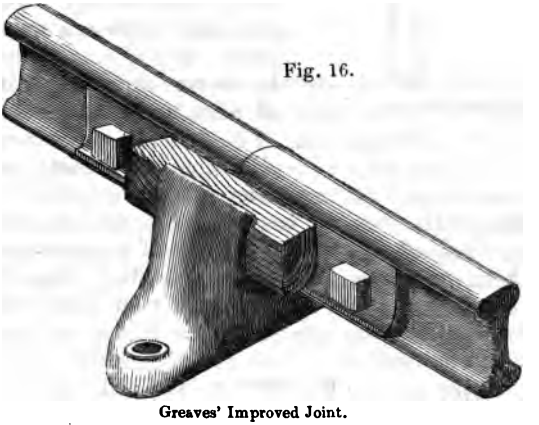


Fig. 16.

Greaves' Improved Joint.

In another plan, a chair with a circular base has a plate to fill the hollow of the rail, and a vertical wood key to secure it (Fig. 17).

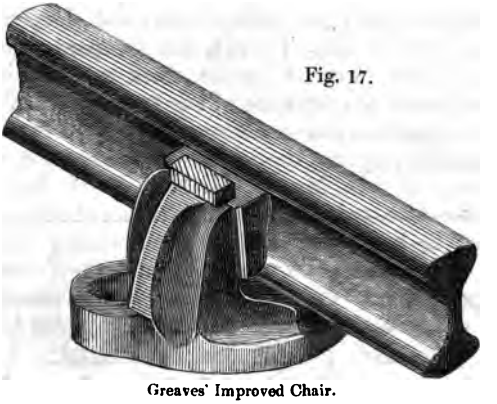


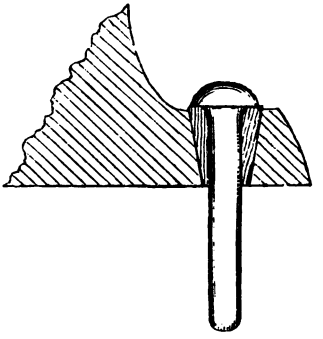
Fig. 17.

Greaves' Improved Chair.

[1] It has since been applied to one of the Indian Railways.—W. B. A.

He has also proposed a method for preventing the head of a chair spike wearing, by surrounding it with a ferrule of wood (Fig. 18).

Fig. 18.



Greaves' Spoke Protector.

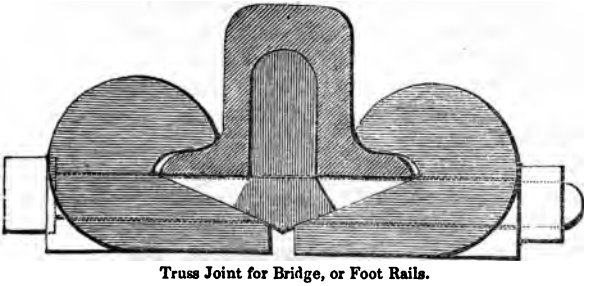
This concludes the various kinds of fastenings used with double I rails.

The foot rail, as originally used, merely rested on the timber, like the bridge rail; but rapid destruction at the joints involved the necessity of a remedy. The common plan was to form a shoe of a bent plate. It is obvious, that there can be no vertical strength in this kind of joint, and that it must bend up and down under constant use. The foot rail was sometimes used in the United States, with a peculiar kind of fish joint, having holes pierced through, so that there was scarcely anything left of the fish. Subsequently, the rail has been increased in height, and a good fish is obtained, but at the expense of a more unsteady rail. The brackets, or knees, previously described (Fig. 11), would support the rail, and at the same time prevent lateral rocking.

The first joint that was adapted to the bridge rail was a dovetail chair; it was used on the Great Southern of Ireland,[1] but it was not effective enough to constitute the rail "a beam fixed at the ends." A subsequent arrangement, was that of putting a simple plate on the sleeper below the joint. This, however, was found insufficient. The next plan was to put a ribbed plate on the sleeper under the rail, and another plain plate below the sleeper, bolting together the rails, plates, and sleepers, with four bolts passing through all. Though the sleepers, which were of the transverse kind, were 6 inches thick and 12 inches wide, they could not resist the pressure of the trains. They were simply a compressible packing; and although the rails were very firm and solid, in other respects, the joints were constantly out of order. In consequence of this, Mr. G. M. Miller, (M. Inst. C.E.,) the engineer of the line, remarked to the Author, that a good joint, similar to that he had introduced for the double I rail, was necessary for the bridge rail. To meet this want, the Author designed the following method (Fig. 19):—Two side castings, each 12 inches in length, press in the angle formed by the rails and the

[1] *Vide* "Description of the Rails, Sleepers, and Fastenings, on the Dublin and Drogheda Railway." By G. W. Hemans. Minutes of Proceedings Inst. C.E., vol. v., pp. 233 to 239.

Fig. 19.



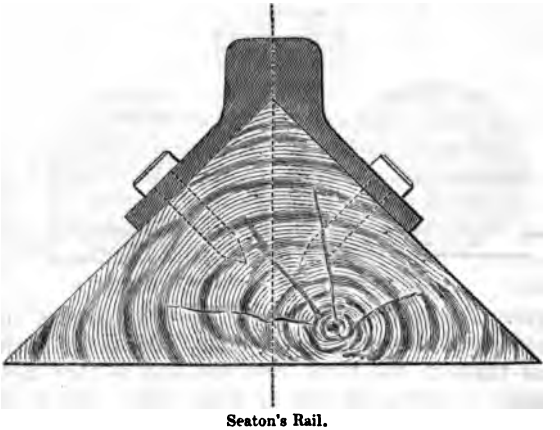
Truss Joint for Bridge, or Foot Rails.

side flanges. An iron tongue-piece, also 12 inches in length, fills the hollow of the rail. Two bolts, $\frac{7}{8}$ths of an inch in diameter, pass through the three castings, and as they tighten, the side castings compress on the inclined plane, where they join, and produce a firm joint which is not found to get loose. This joint forms a base about 1 foot square, under which the ballast is packed, and the expense of providing a new sleeper, 12 inches by 6 inches, to replace that destroyed by wear, is dispensed with; the intermediate cross sleepers, without displacing them, approach nearly to the joint. This system, called the "Truss Joint," is now used on the Great Southern of Ireland, and on the Belfast and Ballymena Railways. It has the advantage of being applicable, without any preparation, or removal of the rails. When used on lines with longitudinal timbers, it is simply required to cut away the timber, to make room for the castings below the rail. Mr. Charles Lanyon, (M. Inst. C.E.,) the Engineer of the Belfast and Ballymena line, has addressed a letter to the Author, in which he remarks, that the experience he has gained of the "Truss Joint" for the bridge rail, enables him to speak very favourably of it, and that he contemplated using it extensively in the renewal of the permanent way of that line.

Mr. G. M. Miller, writing to the Author, said that eighty yards had been laid down on this system, in the autumn of 1854, near Inchicore, and similar lengths, near Athy and Kildare, shortly afterwards. In the following spring half-a-mile was laid on the up line near Strafford. In the latter case the width of the flanges of the rail was reduced, so that the castings did not require to be so heavy. One centre-piece having been broken, it was deemed advisable to replace all the pieces with others of increased proportions. This was done in the summer of 1855. Since then they have stood well. Some have recently been put down with one $1\frac{1}{4}$ inch bolt, which answer well.

In a modification of the bridge rail by Mr. Seaton (Fig. 20), the head of the rail is made solid, and the flanges are bent down

Fig. 20.



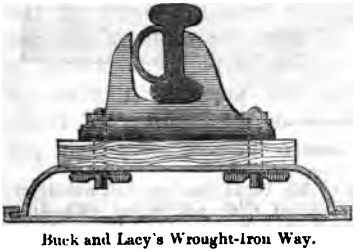
Seaton's Rail.

at an angle of 45°. It is bolted, or screwed, to a triangular timber, with the apex upwards. Mr. Seaton takes credit for reducing the amount of timber by one half, while increasing the bearing surface on the ballast, by cutting the bulks diagonally, and also for increasing the bearing surface of the rail on the timber, from five inches to ten inches, as he seems to assume that the pressure will be on the two faces of the timbers, at right angles, and not vertically.

The uncertainty of the duration of timber sleepers, early induced the use of stone blocks, undoubtedly the best material as a foundation, but requiring some elastic medium between the rail and the stone; for, as it has been remarked by Mr. R. Stephenson, M.P., President, absolutely rigid rails are impracticable for very high speeds.

The failure in the stone blocks, as applied, led to further attempts to construct permanent way wholly of iron. From the first use of iron rails, as tramways, experiments had been made in this direction. In the slate-quarries of Wales, the edge rail proper has long been used, formed of round wrought-iron bars, connected together by iron gauge-bars, and laid upon the ground without sleepers.

Fig. 21.



Buck and Lacy's Wrought-Iron Way.

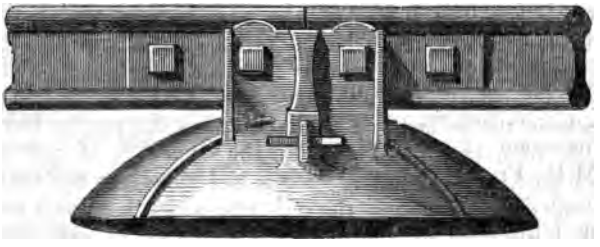
In 1845, the late Mr. G. W. Buck, (M. Inst. C. E.,) in conjunction with Mr. H. Lacy, produced a system of Wrought-iron Way, in which, "The iron sleepers, whether whole, or in short lengths, may be used without chairs, or with them" (Fig. 21). In the former case a bridge rail,

or a foot rail, may be bolted down upon them; whilst in the latter, the double I rail was proposed to be fixed in chairs, by tubular keys of iron,[1] and the chairs were fastened down to the sleepers, by slot bolts and keys, a piece of wood being introduced between them. The sleepers were inverted troughs, similar in section to one form of the saddle-back rail, subsequently patented by Mr. W. H. Barlow. The trough was formed of sheet iron, with a flat top, and the sides bent down to an angle. When made of thin iron, small tie-rods were used, to prevent the iron from spreading out.

In May 1847, Mr. John Reynolds produced a permanent way of iron,[2] with an internal wood packing, which, in a modified form, was tried on the Great Western Railway. It was generally known, as the system of "hog-trough metals;" they were continuous longitudinals, bearing on the ballast, without the use of sleepers, or stone blocks. This form is steadier in the ballast than the inverted trough of Mr. Barlow. This combination of timber and cast-iron is shown in Plate 2, Fig. 9.

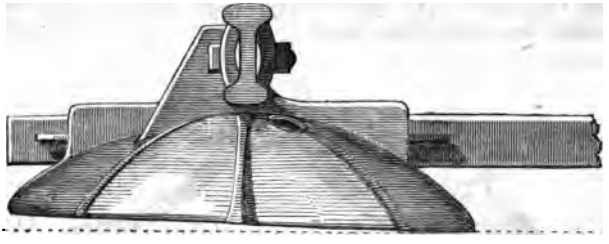
In 1846, Mr. H. Greaves brought out the spheroidal iron sleepers, each with its chair cast on it; representing, in general structure, neither the longitudinal, nor the transverse sleepers, but the stone-block system (Figs. 22 and 23). The most recent

Fig. 22.



Greaves' Improved Spheroidal Iron Sleepers.

Fig. 23.



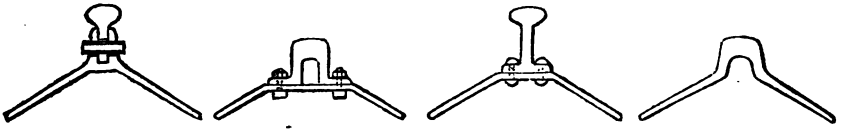
Greaves' Improvements in Fishing.

[1] This idea was subsequently patented by Mr. W. H. Barlow, and was described by him to the Institution. *Vide* Min. Proc. Inst. C.E., vol. iv. pp. 49 to 56.
[2] *Vide* Transactions Inst. C.E., vol. ii., pp. 78 to 86.

improvement made by Mr. Greaves in these sleepers is, ribbing them on the outside, and in fish-jointing the rails, placing fishes within the chair-heads, and bolting through the chairs, and also externally to the chairs.

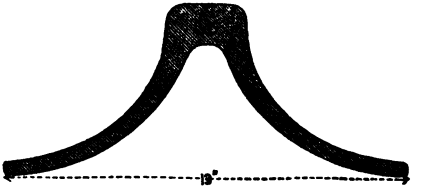
In January 1849, Mr. W. H. Barlow produced a rail, called the "saddle-back rail,"[1] intended to dispense altogether with sleepers, like the "hog-trough system" of Mr. Reynolds, but, in this case, the "hog-trough" was turned upside down. The Author had carefully examined the drawings of this rail, and in his Paper of 1852,[2] he criticised its mechanical qualities, with how much of accuracy the results may now verify. The rail, as specified, is of four forms (Fig. 24). The first is a trough, with the mouth downwards, and

Fig. 24.



with a pair of horns projecting upwards, between which is placed a single T rail, keyed in transversely through the horns and the rail, by tubular iron keys. The second is an inverted trough, with a bridge rail bolted to it. Very great stress would thus be brought on the bolts, as the rail springs under the load. The third is a foot-rail, riveted down to a similar trough, and, consequently, having the same defect in the fastenings. This rail is, also, so much elevated above the base, that it could not possibly be steady in the ballast. The fourth takes the precise form of the ridge-tile of a house. Probably the difficulty, if not impossibility of packing, or keeping such a rail steady in the ballast, led to the next modification—the only one which has been used, and even that can only be kept quiet by a system of sufficient cross-sleepers. The rail, as used, is in fact merely a bridge rail, with an extended base, and the sides placed at an angle instead of being curved (Fig. 25). The first Barlow rails were about

Fig. 25.



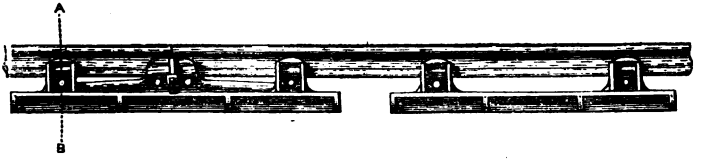
Mr. W. H. Barlow's Saddle-back Rail.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. ix., pp. 387 to 401.
[2] Ibid., vol. xi., pp. 244 to 273.

125 lbs. per yard. Whether from any difficulty of manufacture, or simply from a desire for cheapness, they were gradually reduced to 92 lbs. per yard. The original rails were to be held together with angle-iron ties, at intervals of 10 feet. These, it is evident, could neither prevent the rails from rocking, nor spreading; therefore a T-iron tie was first substituted for the angle iron, and after that iron sleepers, similar to the rail itself, at intervals of 9 feet. This being found insufficient, transverse triangular wooden sleepers were finally adopted, the rails being notched into the wood, and held down by dogs. On the Eastern Counties Line, the rails were used with ordinary transverse sleepers. The defects of this rail are obvious. As the head wears, the tendency to spread out increases. The bearing surface on the ballast does not extend to the whole width, as the hollow does not retain the packing, but serves as an inverted cup, to suck up and retain the moisture. The packing is difficult of access, and the necessary opening of the ballast to get the beater to work is considerable; whilst the connection at the joint is the mere riveting together of two thicknesses of boiler plate, affording no vertical strength, unless the ends of the rails abut firmly, without any allowance for expansion and contraction: and even when abutting, the strain on the rivets is excessive. The rail has been laid down on many lines. The Author believes, however, that it is only partially used on the Midland Railway, by Mr. W. H. Barlow himself; that it is not satisfactory on the Welsh lines; and that it is stated, by some French Engineers, to be neither "logical" in theory, nor available in practice.

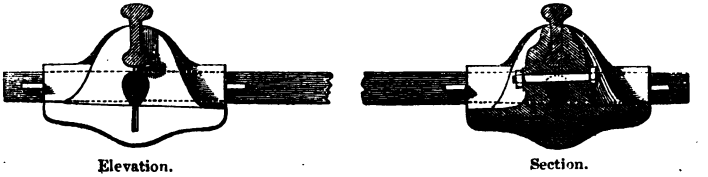
In June, 1849, Mr. Peter W. Barlow, (M. Inst. C. E.,) produced a cast-iron way in two varieties. One (Figs. 26 and 27) was composed

Fig. 26.



Mr. P. W. Barlow's Cast-iron Sleepers.

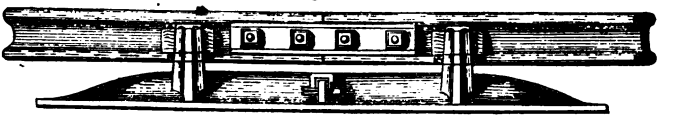
Fig. 27.



Elevation. Section.

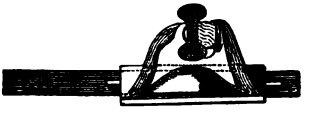
of half-plates 3 feet in length, with two chairs cast on them, also in halves, for intermediates, and longer ones with three chairs for the joints, the halves being bolted together below the rails. In the other variety, the plates were solid, with the chairs cast on them, the rails being fastened by keys in the usual way. The object was to make, not merely a chemically durable sleeper, but a cheap one, and to this idea of cheapness the mechanical strength was sacrificed. The system of bolted sleepers was laid down on the South Eastern Line, where the rails were also reduced from 75 lbs. to 65 lbs. per yard, on the presumption that the novel system of intermittent longitudinal sleepers would strengthen them. The result was a failure. On the Londonderry and Enniskillen Railway, the same system was adopted, but the sleepers were nearly double in weight, so that the result was favourable mechanically, but not at a low cost. The cast-iron sleepers, with chairs and wood keys (Figs. 28 and 29), were formed with a

Fig. 28.



Mr. W. H. Barlow's Cast-iron Fish-joint Sleeper, as used on the Midland Railway.

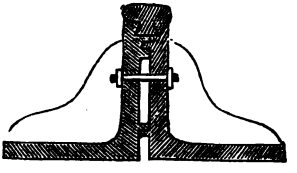
Fig. 29.



Elevation.

hollow rising bottom, probably to save metal. But this involves one of the objections to the "saddle-back rail," the sucking-up of moisture, which is retained by the impervious iron. In this plan Mr. Barlow was anticipated by Mr. John Day, who in January 1835, specified his cast-iron base-plates in two parts (Fig. 30), the difference being that Mr. Day proposed that the rail-bearing should be continuous, whilst Mr. Barlow used chair-heads.

Fig. 30.



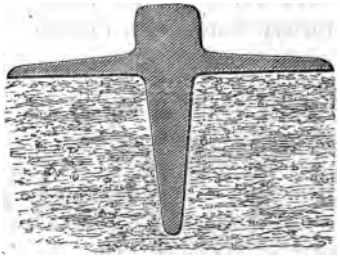
Day's Cast-iron Base Plates, in two parts.

In 1850, Mr. James Samuel, (M. Inst. C. E.,) produced his cast-iron sleepers, with the rails bedded in timber, in rivalry with Mr. Barlow's. The casting was simpler, but the wedging of the wood into the cast iron required great strength of metal to resist it. It was a trough of cast iron, with timber in it, analogous to

the inverted "hog-trough" of Mr. Reynolds, but with the difference of being in short lengths, and not continuous.

In 1851, the Author produced the "Girder Rail" (Fig. 31), both solid and compound, the typical form being a T section, with the broad bearing surface on the ballast, close to the tread of the rails, whilst the depth of the rail was continued with a keel below the bearing surface. In this mode, both vertical and lateral strength were attained, without any tendency to rock, whilst less ballast, probably not one-half, was required; the labour of packing was also reduced to mere surface work, and the drainage was much easier.

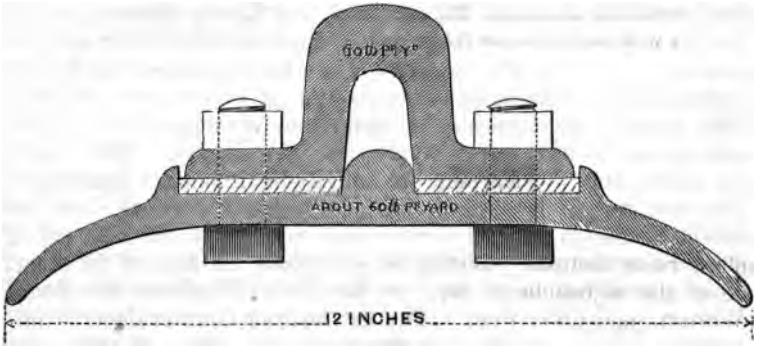
Fig. 31.



Adams' Girder Rail.

In 1852, Mr. J. J. Macdonnell (M. Inst. C. E.) produced a bridge rail, with a longitudinal iron bearing (Fig. 32). The

Fig. 32.

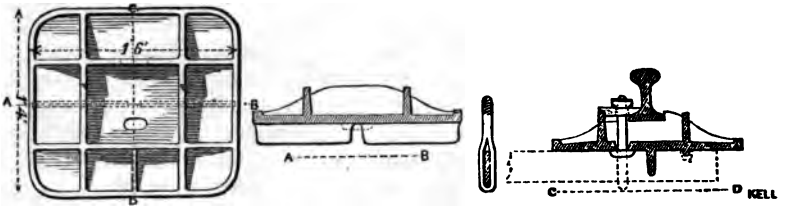


bearing is curved downwards apparently for the purpose of giving vertical strength. A centre and two side-ribs are rolled on the upper side of the plate, between which lie the lower bearing flanges of the rail, resting on strips of timber, the rails and bearers being held together by vertical bolts. It is supposed that these strips of timber will not crush, owing to their confined position between the ribs. It is obvious, that this rail must depend on the ballast for its vertical strength, and that it has a tendency to suck up water below. The joints would be weak, unless stiffened; and probably the best mode of doing this would be, either to bolt a short length of bridge rail below, or else, a deep T iron, making

it take the rail bolts, thus giving about 6½ inches vertical depth. This rail is said to answer well on the Bristol and Exeter Line. The form is evidently much stronger, to resist lateral spreading-out, than that of the saddle-back.[1]

In 1853, Mr. De Bergue, (Assoc. Inst. C. E.,) produced a new variety of iron way, Fig. 33. A foot rail is laid on a series of cast-

Fig. 33.



iron sleepers, formed of a flat table, with a longitudinal rib below. To strengthen the table, a series of thin ribs, as a network, are cast on the upper side. A lug is also cast to take one edge of the rail, and a loose slip, of a wedge-form, with a bolt, is made to take the other side. The bolt has an eye, instead of a head, similar to that shown, in Messrs. Buck and Lacy's specification, in 1845, to take the cross-tie bar below, which is lap-notched into the longitudinal rib of the sleeper. The whole arrangement is very ingenious, producing a considerable amount of strength with very little metal. Mechanically, however, the arrangement is disadvantageous, as the rail is a prop on the sleeper. The joints are fished, and the sleepers are longitudinal, but not continuous. The foot rail, it is obvious, has less vertical strength than the double I, though stiffer laterally, and to produce the best effect, it would be necessary to abut these sleepers one against the other. This system has been tried on the Great Northern, the South Western, and other lines. The flat bearing is an evident advantage, as compared with the "saddle-back rail." If these cast sleepers were in the form of inverted troughs, it would be impossible to keep the line in order. The notch in the lower rib of the casting having been found to be disadvantageous, in a sample subsequently laid on the South Western Railway, Mr. De Bergue divided the lower rib into two parts, and compensated for it by applying an upper rib—a much better disposition of metal, placing the cast rib in compression instead of tension. The Engineer of the South Western line states, after many months' experience, that it has cost less for maintenance than the ordinary

[1] Since this was written the Macdonnell rail has been adopted on the Bridport line.—W. B. A.

way. The area of surface on the ballast is equivalent to a continuous longitudinal way 9 inches in width under each rail.

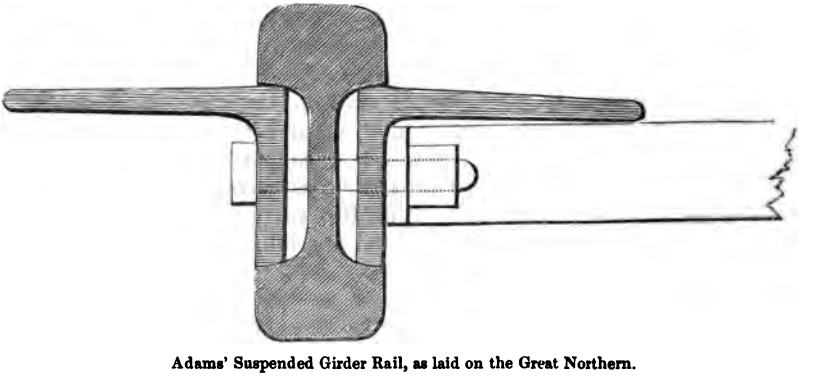
The next system produced was a modification, by the Author, of his girder rail of 1851, in which he has attempted to combine the requisite conditions of lateral and vertical stiffness with easy manufacture and uniform strength throughout. The rail is double headed, the heads being deep enough to clear the wheel flanges, and to allow for wear, without permitting them to infringe on the rail bearers. The vertical rib connecting the two heads, being analogous to the plate girders of bridges, is light. The object is, not to sustain a load upon an insistent web, but to connect the top and bottom tables with such a total depth as will give the requisite strength; while the rail is suspended beneath the upper table, and forms a keel below the bearers, giving firm surface hold in the ballast. The total depth of the rail, as applied, is 7 inches, the heads, or tables, being $1\frac{3}{4}$ inch in depth, and 2 inches in width. This gives, practically, as much bearing surface to the wheel as the ordinary double I rail, of $2\frac{1}{2}$ inches in width, because when by wear more than $1\frac{3}{4}$ inch of width comes into bearing, the sides, which resemble mouldings, crush down for want of support. The early rails were only $1\frac{3}{4}$ inches in width, and were subsequently widened, to give lateral stiffness between the sleepers. The ordinary double I rail, being supported from the base, must necessarily have the vertical rib of sufficient depth not to buckle under the load; and the projecting head being self supported, must have such a form as will tend to prevent it from breaking off. If the side channels were made with square shoulders, it would not be durable. The rail is, therefore, made with a reinforced angle to the rib. But the girder rail having a continuous support on angle brackets, or bearers, throughout its whole length, can be formed with nearly square shoulders to the side channels. The angle brackets are bolted to and through the rails, and breaking joint with the rails, and with each other, produce a very equable strength throughout; whilst the rail, being suspended and not insistent, can be made much lighter than would be possible, were it supported on its lower table in the ordinary method. The angle brackets are about $6\frac{1}{4}$ inches in width, and when bolted to the rail, make up a total width of $13\frac{1}{4}$ inches, equivalent to the bearing-surface of a cross-sleeper road, with the sleepers 2 feet 6 inches apart. Consequently, as the height of the rail-tread is only $2\frac{1}{2}$ inches above the bearing on the ballast, and the keel below is $4\frac{1}{2}$ inches in depth, the maximum security against rocking, or other disturbance in the ballast, is attained. The simplicity of structure is evidenced by the fewness of the parts, being only four types, or forms,—the rail—the bracket—the bolt—and the tie-bar—all of wrought iron. There is very little strain on the bolts, as the

brackets fit securely in the square angles of the rail. The lateral resistance to blows is also considerable.

Experiments have been tried for comparing the strength of the joints of this rail, and the fish-joint of the double I. The force was applied by means of a hydraulic press. The bearings were 7 feet 6 inches apart. With a pressure of eight tons, the fish-joint bolts were broken across; whilst with twelve tons, the girder-rail bolts were unmoved, though the brackets were bent to a considerable angle. With a pressure of twenty tons, applied horizontally across the width of the brackets, the yield was one inch, and within the elastic limit of the rail, which returned to its original position, on the removal of the pressure.

A sample of this system was laid down by Mr. J. Cubitt (M. Inst. C.E.), about the end of the year 1855, on the up coal line of the Great Northern Railway, at King's Cross. The rail is 84 lbs. per yard, and the angle brackets 42 lbs. per yard (Fig. 34). This

Fig. 34.



Adams' Suspended Girder Rail, as laid on the Great Northern.

part of the line is on a curve, and on an incline of 1 in 110, with frequent trains of 300 tons gross. Authority has recently been given to the Engineer, Mr. Brydone, to lay down a further portion of the "Suspended Girder Rail." The ballast used was only one-half the ordinary quantity, and the labour of maintenance is stated to be less than half that of the common way. As the bearing is on the surface, the packing is easy, and on lifting the rails, an extent of about 40 feet is operated on by one leverage. In fact, though not rigid but elastic, this rail forms at the same time a girder and a tension cable. On one occasion, a portion of the ballast was cleared away for 6 feet in length beneath the joint, leaving the rail suspended like a bridge; when very little deflection occurred, during the passage of the engine, the rail being in reality a beam. The laying down is very simple;

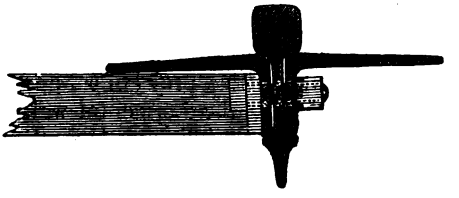
and common labourers cannot make any error, either in the gauge, or in the pitch of the rails, as both are regulated by the tie-bars. The bolts and nuts are firmly held in the matrix, formed of the compressed ballast, and are not subject to move. It is self-draining, the water squeezing away from the horizontal surface-webs, instead of forming ponds below, and the direct entrance of rain is prevented by the overlap on the ballast.

In the processes of "maintenance of way," packing the sleepers is a very important item. In proportion to the elevation of the rail-surface above the bearing-surface of the sleepers on the ballast, so,—other things being equal,—is the tendency to rocking and displacement, and so also is the cost of packing; because the lower the bearing in the ballast, the more material there is to open out in order to pack beneath the sleepers. It is, therefore, obviously important to have the bearing, if possible, on the dry upper surface, instead of below it, supposing that provision is always made to preserve the gauge, and to prevent lateral shifting.

At the recommendation of Mr. R. Stephenson, M.P., President, and Mr. Joseph Locke, M.P., V.P., who have carefully examined the sample at King's Cross, a number of miles have been ordered, for the purpose of laying down on the London and North Western Railway. M. Flachat, (M. Inst. C. E.,) the Engineer of many of the French lines, has also ordered a sample to be laid down. Mr. James I. Berkley (M. Inst. C.E.) has recommended it to be tried on the Great Indian Peninsula Railway, and Mr. J. A. Longridge (M. Inst. C.E.) has advised its adoption on the South Eastern and Calcutta.

A variation from the above form is made by using a single-headed rail, with provision below to give bearings to the angle brackets. (Fig. 35.)

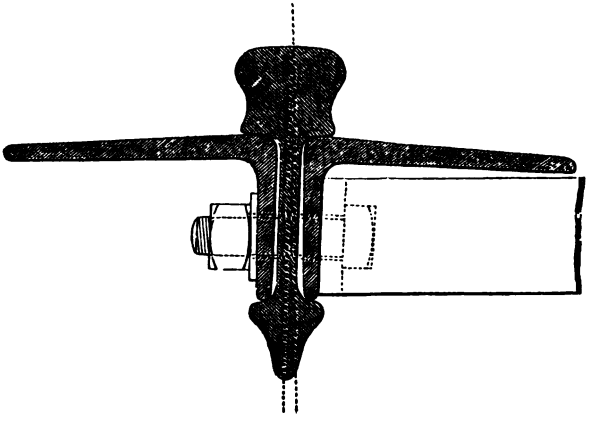
Fig. 35.



Adams' Single-headed Suspended Girder Rail.

The weight of this rail is 62 lbs. per yard, and the single brackets are 31 lbs. per yard. The section adopted for the Bombay and Baroda Railway is shown in Fig. 36, page 30. The depth of the rail is 7 inches. The whole of the iron-work is to be dipped, when warm, in linseed oil.

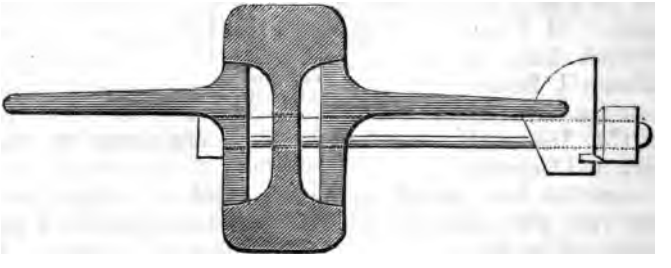
Fig. 36.



Adams' Suspended Girder Rail, to be used on the Bombay and Baroda Railway.

The next sample is an ordinary double-headed rail, 65 lbs. per yard, and 5 inches in depth, the vertical web being diminished in thickness (Fig. 37). The bearing of the angle brackets on the

Fig. 37.

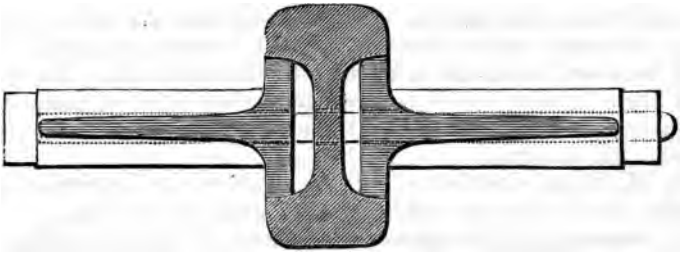


Double-headed Rail, of ordinary depth, suspended on angle brackets.

ballast is 12 inches in width, being equal to a cross-sleeper road with the sleepers 3 feet apart. In order to keep the bolt-holes in the centre of the web, to admit of the rail being readily reversed, the angle brackets are rolled with a projecting lip above; the bolts passing through close beneath the horizontal webs, and the nuts are secured upon small castings, clipping one edge of the angle plates. A small key, driven between the nut and the casting, renders the whole secure.

In another variety, cast T iron angle brackets (Fig. 38.), each 3 inches in depth and 5½ inches in width, are substituted for wrought iron, the castings being about 3 feet in length and weighing 35 lbs. each. Long bolts pass through ribbed projections either at the centre, or at the ends of the castings, or short bolts may be used in recesses, or either keys, or pins, as preferred.

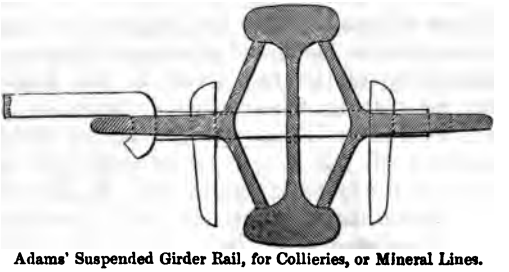
Fig. 38.



Double-headed Rail, with cast T iron angle brackets.

A light girder rail, wholly of wrought iron, and adapted to collieries, or mineral lines, or districts where light engines are used, is represented in Fig. 39. The rail is double headed, 5 inches in

Fig. 39.



Adams' Suspended Girder Rail, for Collieries, or Mineral Lines.

depth, and weighs 40 lbs per yard, the T angle brackets give a width of 9 inches continuous to each rail; an area which, on the South Western Railway, has been found equivalent to a first-class cross sleeper way. The space between the rail and the T angle brackets may be made to subserve the purpose of drainage. The T angle brackets are connected to the rails by bolts and keys 3 feet apart, and tie-bars are applied to any number of the bolts, which are secured by the same keys. The heads of the rails are only 2 inches wide, but they are sufficiently stiffened laterally by the angle brackets, and though the total weight is only 130 tons per mile, an efficient system for moderate loads is attained at a low cost.

The advantages which the Author proposes to attain by this system of Permanent Way are as follows:—

1. The use of tough and elastic material, which, when worn out, has considerable value, entirely dispensing with the decaying timber.

2. A structure of few types and parts which can be furnished complete by the iron-masters, is easily transportable, and needs only the commonest kind of labour to lay it.

3. A continuous bearing on the dry upper surface of the ballast, instead of in a deep trench, which, if non-porous, becomes a pond.

4. Increased vertical strength, without increased weight of rail, and increased horizontal strength with efficient joints. The rails and angle brackets would be arranged so as to break joint, thus forming a strong girder to bear the load, and analogous to an iron cable.

5. Minimum elevation of rail tread above the bearing on the ballast, diminishing the risk of trains getting off the line.

6. Suspension by the upper table instead of insistent bearing on the lower table, so that in the case of a double-headed rail, the tables are not damaged, and the rails can be reversed, end for end, or upside down.

7. A reduction in the expense of laying down, in the quantity of ballast required, and a saving in maintenance.

How far the Author has been successful, or otherwise, in the attainment of these objects is left to the judgment of engineers.

The objections that he has heard of are as follows:—

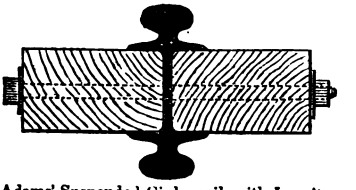
1. The proximity of the rail tread to the angle brackets, giving facility for placing mischievous obstacles on the line. 2. The chance of ice accumulating near the rail in winter, and thus throwing the train off. 3. The want of sufficient hold in the ground to prevent the rails springing up. 4. The risk of wear and abrasion between the rails and the angle brackets on which they bear. 5. The chance of the bolts getting loose. 6. The difficulty of getting at the bolts to tighten them. 7. The apparent difficulty of bending the rails and angle brackets laterally to suit curves.

On these objections the Author has to observe,—1. As to mischievous obstacles, the facility is equal in the case of all rails. 2. Ice lying on the iron plates would be much more easily broken by the wheel flanges, than ice bedded on and in the ground, by reason of the lessened thickness. Moreover, to set against these mischances, there is the greatly diminished risk, owing to better fastenings. 3. The hold in the ground is of less consequence with a vertically stiff rail, distributing the load over a large space, than with a flexible rail, and there is, moreover, 4½ inches depth of keel roughened by bolts, and connected to tie-bars, to hold in the ballast. 4. Experience shows that the bolts, matriced into the ballast, have no tendency to get loose, and, moreover, they can be readily keyed, to render their fixture absolute. If this is not sufficient, the lower edges of the angles can be dovetailed to the rail, in such a way that all stress is removed from the bolts. 5. The bolts are easily accessible with a ratchet spanner, boring out an opening in the ballast. 6. By cross slotting the angle brackets for two-thirds of their width, at intervals of 3 feet, or by pressing

the angles between the rolls, or by hammering and extending one edge, and corrugating and diminishing the other, any desired curve may be attained.

For countries where timber is cheap and iron dear, girder rails may be prepared with double-heads, and deep side channels, with broad lips, into which timber may be bolted, instead of angle brackets, the joints being formed with wrought-iron angle plates. The rail resembles in form two foot rails, connected by a deep vertical web (Fig. 40).

Fig. 40.



Adams' Suspended Girder-rail, with Longitudinal Timbers.

Mr. Burleigh has had on trial, for about two years, on the Great Northern Railway, a system of cast-iron way, in the structure of which he has displayed great judgment (Fig. 15, p. 16). He forms the cast wedge chair, before described, into a cast sleeper, by extending the base, which presents a wedge form on the plan. Opposite, chair sleepers are connected by a wrought tie-bar, which wedges upon the sleepers, and serves as a tie to strengthen each sleeper while keeping it in position Thus the whole system of fastening is by wedges so arranged that the motion of the trains tends to tighten them. The rails are of the usual double-headed section. This is altogether a simple and effective system of cast-iron way. As a variation, these chair sleepers are sometimes used with an elastic wrought-iron key, made to expand in the driving against a wedge-shape lip on the jaw of the chair.

The last system of iron way produced is that of Mr. Spencer. It is a foot rail, like Mr. De Bergue's, with bolted fishes at the joints. It is bolted down to continuous longitudinal sleepers of corrugated iron; the corrugations being transverse to the rail, and the total width fifteen inches. There is considerable complication of parts. The rail—fish—fish-bolt—a saddle for each corrugation—vertical bolt—joint saddle—rivet—bolt—tie-bar—and tie-bar bolt, —in all nine types, or forms. It has been laid down on the Tilbury Line, and is said to be firmer than the sleeper road. Its great width of continuous bearing, though not laterally stiff, will account for this; but it is evident, that the vertical stiffness can only be supplied by the ballast, and on a yielding structure the line would be a succession of waves. Nor are the corrugations favourable to drainage, as the downward curves on a non-porous stratum would form a succession of small ponds, liable to increase by the bending of the rail vertically.

This concludes the different systems of permanent way, put in practice up to the present time.

The question of cost must vary with times and circumstances. A considerable saving in ballast will afford an increase in iron. It must not be forgotten, that the class of "way" available for engines weghing 15 tons, will not suffice for those of 30 tons and upwards. In a permanent way, or a "way" intended to be permanent, it is a great fallacy to stint material in first cost, and quintuple the expense in maintenance. Even with the cross sleepers, it will be found, that under the increased loads they spring across the middle, the ends rising and falling. If this is prevented by hollowing out the ballast in the middle, the result is diminution of bearing surface on the ballast, and consequent sinking. It will, probably, be found, that cross sleepers, 7 inches in depth and 12 inches in width, by preventing springing, will give greater durability to the timber, and a less amount of maintenance, in displacing fastenings and renewing ballast.

In the foregoing Paper, the Author has confined himself to treating of matters in actual practice, in accordance with the rules of the Institution. In the criticisms, whether of his own productions, or those of other persons, he has endeavoured, conscientiously, to examine them, according to mechanical principles; subject, of course, to the natural bias which every mind must have in favour of its own production. His remarks are now open to the criticism of others, and whilst he believes his own system to possess many and great advantages, he will gladly welcome any new improvement made by others, for facilitating transit, even though rendering his own past efforts useless, regarding it only as an incentive to a further wholesome competition.

The Paper is illustrated by a large number of diagrams, from which Plate 2 and the woodcuts, Figs. 1 to 40, are in part compiled. There are also exhibited models and specimens of most of the systems of permanent way described in the Paper, a great number of which are contributed by the Permanent Way Company.

A Table of particulars of the various classes of permanent way is given in the Appendix, which faces this page.

PLATE 2. VOL. XVI.

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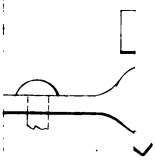
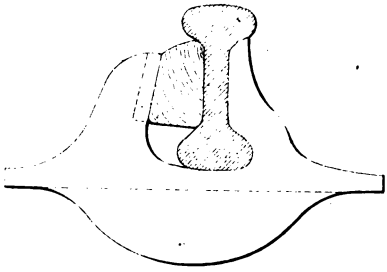


Fig. 19.
P. M. Parsons, March, 1854.
Wood lined Chair.



forming a
the Rails.

Fig. 22.
W. B. Adams, July, 1856.

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